

CLAIMS

What is claimed is:

- 5 1. A functionally-graded metal substrate comprising:  
a functional insert;  
a surrounding body;  
wherein the functional insert and the surrounding body  
are two metal compositions in the x-y plane of the  
substrate; and,  
10 wherein the surrounding body surrounds the functional  
insert.
2. The functionally-graded metal substrate of claim 1  
wherein the surrounding body surrounds the functional insert  
15 in at least two dimensions.
3. The functionally-graded metal substrate of claim 1  
wherein the functional insert extends from a top surface of  
the functionally-graded metal substrate to the bottom  
20 surface of the substrate.
4. The functionally-graded metal substrate of claim 1  
wherein the functional insert extends from one surface of  
the substrate to an internal location of the substrate.
- 25 5. The functionally-graded metal substrate of claim 1  
having a density of at least about 90% of theoretical.
6. The functionally-graded metal substrate of claim 1  
30 wherein the functional insert comprises a metal composition  
selected from the group consisting of copper, nickel, iron,  
beryllium, aluminum, silver, copper-beryllium, copper-zinc  
(bronze), copper-tin (brass), 64% iron/36% nickel (Invar™)  
a and, 54% iron/29% nickel/17% cobalt (Kovar™), copper-iron,  
35 nickel-niobium, nickel-silver, nickel-copper, iron-copper,

iron-copper-carbon, iron-copper-nickel, iron-chromium, iron-copper-tin, copper-nickel-titanium-aluminum, nickel-copper-titanium, copper/tungsten, copper/molybdenum, aluminum/silicon carbide, aluminum/aluminum nitride, copper/aluminum, silver/Invar<sup>TM</sup>, copper/cubic boron nitride, copper/diamond and copper/high conductivity carbon fiber.

a and combinations thereof

7. The functionally-graded metal substrate of claim 1 wherein the surrounding body comprises a metal composition selected from the group consisting of copper, nickel, iron, beryllium, aluminum, silver, copper-beryllium, copper-zinc (bronze), copper-tin (brass), 64% iron/36% nickel (Invar<sup>TM</sup>) ~~and~~ 54% iron/29% nickel/17% cobalt (Kovar<sup>TM</sup>), copper-iron, nickel-niobium, nickel-silver, nickel-copper, iron-copper, iron-copper-carbon, iron-copper-nickel, iron-chromium, iron-copper-tin, copper-nickel-titanium-aluminum, nickel-copper-titanium, copper/tungsten, copper/molybdenum, aluminum/silicon carbide, aluminum/aluminum nitride, copper/aluminum, silver/Invar<sup>TM</sup>, copper/cubic boron nitride, copper/diamond and copper/high conductivity carbon fiber.

a and combinations thereof

8. The functionally-graded metal substrate of claim 1 wherein the surrounding body is a copper/tungsten MMC containing from about 5% to about 50% by weight copper, and wherein the functional insert is a copper/tungsten MMC containing from about 20% to about 80% copper.

9. The functionally-graded metal substrate of claim 1 wherein the surrounding body is a copper/tungsten MMC containing from about 5% to about 40% by weight copper, and wherein the functional insert is a copper/tungsten MMC containing from about 30% to about 50% copper.

10. The functionally-graded metal substrate of claim 1 wherein the surrounding body is a copper/tungsten MMC containing from about 10% to about 30% by weight copper, and  
5 wherein the functional insert is a copper/tungsten MMC containing from about 30% to about 45% copper.

11. The functionally-graded metal substrate of claim 1 wherein both the surrounding body and the functional insert  
10 comprise copper/tungsten or copper/molybdenum, and wherein the concentration of copper in the functional insert is greater than the concentration of copper in the surrounding body.

12. The functionally-graded metal substrate of claim 1 further comprising:  
a heat-generating component attached thereon.

<sup>12</sup>  
13. The functionally-graded metal substrate of claim ~~13~~ wherein the heat-generating component is attached to the  
20 functional insert and wherein the heat-generating component is a chip.

14. The functionally-graded metal substrate of claim 1  
25 wherein the functional insert has a thermal conductivity that ranges from about 200 W/mK to about 400 W/mK and wherein the surrounding body has a CTE that ranges from about 5.6 ppm/°C to about 7.0 ppm/°C.

*Sub 24*  
30 15. A functionally-graded metal substrate comprising:  
a functional insert;  
a surrounding body;  
wherein the functional insert and the surrounding body  
are two metal compositions in the x-y plane of the  
35 substrate;

wherein the surrounding body surrounds the functional insert in at least two dimensions;

wherein the functional insert extends from a top surface of the functionally-graded metal substrate to the bottom surface of the substrate;

wherein the functional insert and the surrounding body comprise a metal composition selected from the group consisting of copper, nickel, iron, beryllium, aluminum, silver, copper-beryllium, copper-zinc (bronze), copper-tin (brass), 64% iron/36% nickel (Invar™) and 54% iron/29% nickel/17% cobalt (Kovar™), copper-iron, nickel-niobium, nickel-silver, nickel-copper, iron-copper, iron-copper-carbon, iron-copper-nickel, iron-chromium, iron-copper-tin, copper-nickel-titanium-aluminum, nickel-copper-titanium, copper/tungsten, copper/molybdenum, aluminum/silicon carbide, aluminum/aluminum nitride, copper/aluminum, silver/Invar™, copper/cubic boron nitride, copper/diamond and copper/high conductivity carbon fiber; and,

wherein the functionally-graded metal substrate has a density of at least about 90% of theoretical.

16. A functionally-graded metal substrate comprising:  
a functional insert;  
a surrounding body;

wherein the functional insert and the surrounding body are two metal compositions in the x-y plane of the substrate;

wherein the surrounding body surrounds the functional insert in at least two dimensions;

wherein the functional insert extends from a top surface of the functionally-graded metal substrate to the bottom surface of the substrate;

wherein the surrounding body is a copper/tungsten MMC containing from about 5% to about 50% by weight copper, and

wherein the functional insert is a copper/tungsten MMC

containing from about 20% to about 80% copper; and,

wherein the functional insert has a thermal conductivity that ranges from about 200 W/mK to about 400 W/mK and wherein the surrounding body has a CTE that ranges from about 5.6 ppm/°C to about 7.0 ppm/°C.

a 17. The functionally-graded metal substrate <sup>of claim 16</sup> further comprising:

A heat-generating component attached thereon.

10 18. A process for making a functionally-graded metal substrate, the process comprising:

filling the cavity of a metal body with a functional insert powder composition; and,

15 sintering the functional insert powder composition.

a 19. The process of claim <sup>18</sup> 19 wherein the metal body is comprised of a metal composition selected from the group consisting of copper, copper oxide, nickel, iron, beryllium, aluminum, silver, copper-beryllium, copper-zinc (bronze), copper-tin (brass), 64% iron/36% nickel (Invar™) and 54% iron/29% nickel/17% cobalt (Kovar™), copper-iron, nickel-niobium, nickel-silver, nickel-copper, iron-copper, iron-copper-carbon, iron-copper-nickel, iron-chromium, iron-copper-tin, copper-nickel-titanium-aluminum, nickel-copper-titanium, copper/tungsten, copper/molybdenum, aluminum/silicon carbide, aluminum/aluminum nitride, copper/aluminum, silver/Invar™, copper/cubic boron nitride, copper/diamond and copper/high conductivity carbon fiber

a 20. The process of claim <sup>18</sup> 19 wherein the functional insert powder composition is comprised of a metal composition selected from the group consisting of copper, nickel, iron, beryllium, aluminum, silver, copper-beryllium, copper-zinc

(bronze), copper-tin (brass), 64% iron/36% nickel (Invar™) and 54% iron/29% nickel/17% cobalt (Kovar™), copper-iron, nickel-niobium, nickel-silver, nickel-copper, iron-copper, iron-copper-carbon, iron-copper-nickel, iron-chromium, iron-copper-tin, copper-nickel-titanium-aluminum, nickel-copper-titanium, copper/tungsten, copper/molybdenum, aluminum/silicon carbide, aluminum/aluminum nitride, copper/aluminum, silver/Invar™, copper/cubic boron nitride, copper/diamond and copper/high conductivity carbon fiber.

a 21. The process of claim ~~19~~<sup>18</sup> wherein the metal body is solid metal.

a 22. The process of claim ~~22~~<sup>18</sup> wherein the functional insert powder composition is a loose powder.

a 23. The process of claim ~~23~~<sup>18</sup> wherein the sintered functional insert is infiltrated with a molten metal compound.

a 24. The process of claim ~~19~~<sup>18</sup> wherein the metal body is a compact of a surrounding body powder composition and the surrounding body powder composition is compacted prior to sintering; and

25 wherein the surrounding body powder composition and the functional insert powder composition are sintered simultaneously.

a 25. The process of claim ~~25~~<sup>24</sup> further comprising:  
30 infiltrating the sintered functional insert composition or the sintered surrounding body composition or both with a molten metal compound.

a 26. The process of claim ~~19~~<sup>18</sup> wherein the metal body is a compact of a surrounding body powder composition and the

surrounding body powder composition is compacted prior to sintering;

wherein the functional insert powder composition is compacted prior to sintering; and,

- 5 wherein the surrounding body powder composition and the functional insert powder composition are sintered simultaneously.

a 27. The process of claim <sup>26</sup> further comprising:

10 infiltrating the sintered surrounding body or the a sintered functional insert or both. *with a molten metal compound*

a 28. The process of claim <sup>27</sup> wherein the process produces a functionally-graded metal substrate that has a least two  
15 discrete portions, a functional insert and a surrounding body, in the x-y plane, and wherein the surrounding body surrounds the functional insert.

a 29. The process of claim <sup>28</sup> wherein the surrounding body powder composition contains copper/tungsten powder; and  
20 wherein copper is present in the amount from about of 5% to about 50% by weight; and  
wherein the functional insert powder composition comprises copper/tungsten powder containing from about 20% to about 80% by weight copper.

25 a 30. The process of claim <sup>29</sup> wherein the molten metal compound is copper.

*del*  
30 ~~31. The process of claim 26 wherein the sintering temperature is about equal to or greater than the melting temperature or the eutectic temperature of at least one metal composition.~~

32. A process for making a functionally-graded metal substrate comprises:

compacting a surrounding body powder composition having a cavity therein;

5 placing a functional insert powder composition into the compact of the surrounding body composition;

sintering the compact containing functional insert powder composition and the compact containing the surrounding body powder composition simultaneously; and,

10 infiltrating the sintered functional insert or the sintered surrounding body or both with a molten metal to form a metal substrate that has a functional insert and a surrounding body that surrounds the functional insert.

15 a <sup>32</sup>33. The process of claim <sup>32</sup>33 wherein the molten metal is a metal that melts at about 1400 deg. C or less.

a <sup>33</sup>34. The process of claim <sup>33</sup>34 wherein the surrounding body surrounds the functional insert in at least two dimensions;  
20 and,

wherein both the surrounding body and the functional insert comprise copper/tungsten or copper/molybdenum, and wherein the concentration of copper in the functional insert is greater than the concentration of copper in the  
25 surrounding body.

a <sup>34</sup>35. The process of claim <sup>34</sup>35 wherein the functional insert extends from a top surface of the functionally-graded metal substrate to the bottom surface of the substrate; and  
30 wherein a heat-generating component is attached to the functional insert.

a <sup>a</sup>36. The process for making a functionally-graded metal substrate <sup>comprising</sup> comprises.



compacting a surrounding body powder composition having a cavity therein;

compacting a functional insert powder composition to form a compact;

5 placing the compact of the functional insert powder composition into the compact of the surrounding body composition; and,

sintering the compact containing functional insert powder composition and the compact containing the  
10 surrounding body powder composition simultaneously.

*a*  
*a* 37. ~~The~~ process for making a functionally-graded metal substrate, the process comprising:

placing a solid functional insert in the cavity of a  
15 solid metal body; and,

bonding the metal body and the functional insert to form a metal substrate having a functional insert and surrounding body in the x-y plane.

20 *a* 38. The process of claim <sup>37</sup>38 wherein bonding is achieved via brazing or pressure-assisted or pressureless diffusion bonding.

*add an* 